A STRUCTURED METHODOLOGY FOR ENTERPRISE MODELING: A CASE STUDY FOR MODELING THE OPERATION OF A BRITISH ORGANIZATION

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SUMMARY: Enterprise Modeling has emerged in an attempt to take a more holistic view of organizations and today it is widely used to describe all activities of modeling any pertinent aspect of an organization's structure and operation in order to improve or reposition selected parts of the organization. Over the last decade, typical applications of Enterprise Modeling were seen in the fields of Business Process Reengineering, the selection and development of Information Systems and in Knowledge Management. Many methods for Enterprise Modeling have emerged, each for a different purpose. Unfortunately organizations, undertaking Enterprise Modeling projects, often fail in achieving the desired objectives or succeed with varying degrees of success. This happens especially when Enterprise Modeling is used for the conceptual design of information systems and can be the result of both the selection of an appropriate modeling method and the communication gap between end users and information systems specialists. In fact, the selection of the right modeling method is not straightforward and could mislead the analysis of business processes, if an inappropriate method is selected. The main objectives of this research are to present guidelines for the selection of the right modeling method, to propose a structured methodology for Enterprise Modeling based on the combined use of the IDEF0 technique and the Dependency Structure Matrix (DSM) and to test the methodology in a real case study. The proposed methodology is an innovative, intuitive and powerful approach to understanding complex interactions, whilst facilitating the management of change and creating a shared vision of business processes. The methodology was tested in a real case study where the entire operation of an organization were modeled and models were used for the definition of functional requirements of a web based collaborative working software tool. The case study was conducted in a British organization, involved in the construction supply chain as a manufacturer and installer of cladding and façade elements. By adopting this methodology, the internal interactions between all the organization's departments (commercial, sales and estimation, design, procurement, manufacturing and project management) and external interactions with external stakeholders (client, architect and site) were modeled. These models were then used to capturing and defining a clear set of functional requirements for the collaborative software, which were communicated to the system developer. Future applications of the methodology are in Business Process Reengineering of companies migrating from a departmentalized arrangement to process based arrangement.

KEYWORDS: Enterprise Modeling, Business process, Integration Definition (IDEF0), Dependency Structure Matrix (DSM), Collaborative Working Software.

1. INTRODUCTION

Enterprise Modeling has raised a considerable interest in many disciplines over the last two decades. There are several definitions of Enterprise Modeling. Vernadat (1996) defines Enterprise Modeling as the process of building models of whole or part of an enterprise (e.g. process models, data models, resource models, new ontologies, etc.). An enterprise model is a representation of the structure, activities, processes, information, resources, people, behavior, goals, and constraints of a business, government, or other enterprises (Mark et al., 1998). Today, Enterprise Modeling is widely used to describe all activities of modeling any pertinent aspect of an organization's structure. Professionals in various disciplines feel the need to describe an enterprise according to prescribed rules in order to be able to pursue specific goals through the modeling. However, the big thrust to Enterprise Modeling has come from the Information Technology. In fact, over the last decade the management information systems have become more important than ever as a result of the introduction and implementation of new methods in design (e.g. concurrent engineering), production (e.g. lean production) and supply chain management (e.g. strategic outsourcing, downstream supply chain and supply chain partnering). A lack of cooperation in sharing the information among the participants has a negative effect on the smooth implementation of projects (Popov et al., 2010). Therefore, stakeholders within the same organization and organizations within the same supply chain require the right information at the right place at the right time throughout the entire organization and supply chain. As a result, information and management information systems (MIS) have become critical elements for the efficient and effective operation of today's project based organizations. Most companies have information systems supporting their core activities, and as companies grow and competitive pressure increase, the dependency on these systems increases also, leading to the necessity of updates in the infrastructure of information systems. Theoretically, when companies grow, every additional employee almost doubles the number of communication channels that the informal network must support (Figure 1) (Sandoe, 2001, p.11). In fact, most companies, while growing, experience an increasing difficulty in communication and coordination. To cope with this increasing difficulty, companies either undertake reengineering projects and implement new management information systems or update existing IT infrastructures. However, many companies fail in achieving this goal or succeed with varying degrees of success and the deployment of new IT solutions within businesses result in the replacement of old problems with new and the expected business benefits not realized (Berghout and Renkema, 2001; Thorp, 2001). Gartner Group studies (cited in Marchand and Peppard, 2008) suggest that 75% of all US IT projects are considered to be failures as they do not deliver what was agreed, miss their deadlines and go over budget (half of the projects exceeded budget by 200%). The reasons of this failure can be attributed to two main factors that often occur simultaneously:

- Writing software for management information systems is still a very specialized job; therefore, its functional requirements are often written by the same people that make the design decisions with the result that the system developed is technology driven rather than business-driven (what the business really requires from the system) (Noran, 2000);

- The lack of understanding of IT needs by the practitioners in the industry results in incorrect and unclear requirements for the IT system which in turn results in an impracticable system (Dawood, 2000).

When these two factors occur simultaneously, they result in a „user-designer communication gap that undermines the successful capture of requirements and implementation of management information systems. In addition, the difference in background, interest and priorities further impede the communication and problem solving among end users and IS specialists (Laudon and Laudon, 2007).
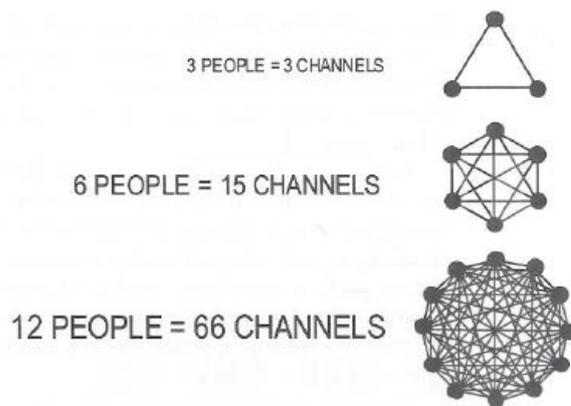
FIG. 1: Communication channels increase exponentially as employees increase (Sandoe, 2001)

Enterprise Modeling plays a major role in filling this communication gap. While there has been a proliferation of Enterprise Modeling methods, there are no clear guidelines in the literature as to what modeling method to select for a specific purpose, although this aspect is crucial for achieving the purpose of modeling. This paper aims at structuring and presenting guidelines for the selection of the right modeling method, presenting an Enterprise Modeling structured methodology based on the combined use of the IDEF0 modeling technique and the Dependency Structure Matrix (DSM) and testing the methodology in a real case study. Background information about the tools used is presented below:

1.1 IDEF0 overview

IDEF0 (Integration Definition) was developed by the US Air Force's Integrated Computer Aided Manufacturing (ICAM) in the late 1980s. There are many different IDEF methods. The complete list of IDEF methods goes from IDEF0 to IDEF14 with IDEF 7 missing from the list. Each method is useful for describing a particular perspective of an enterprise (Roger et al, 1998). The IDEF0 function modeling method is designed to model the decisions, actions and activities of an organization or a system (Mayer et al., 1999). IDEF0 is capable of graphically representing a wide variety of business, manufacturing and other types of enterprise operations to any level of detail. It has two types of graphic notation, the activity box and boundary/interface arrows (Figure 2). Each side of an activity box has a specific meaning:

- Inputs: they are represented by arrows entering the box from the left side. They are resources that will be used and transformed by the activity into outputs (e.g. manufacturing information, raw materials);
- Controls: they are represented by arrows entering the activity box from the top and describe 'why' and 'how' a function is performed. They control, constrain, trigger or regulate the activity (e.g. customer order, business strategy, design requirements);
- Outputs: they are represented by arrows coming out the box from the right side and are the result of the activity (e.g. delivery schedule, recommended design);
- Mechanisms: they are arrows entering the box from the bottom side and they represent the resources (e.g. machines, software, human resources) necessary to perform the activity.

IDEF0 is a top down diagramming technique which goes from the general to the specific, from a single diagram (called top level context diagram) that represents an entire system to more detailed diagrams that explain how the subsections of the system work. Figure 3 shows the decomposition structure used in IDEF0 to describe and decompose each box into greater level of details. The top level context diagram is decomposed into its sub functions, which have more explicit names with specifically named arrows. Then, the second level's boxes are decomposed in turn into sub-function and so on. This decomposition policy and the IDEF0 diagramming are subject to strict syntax and semantic rules (e.g. arrows reporting between child and parents diagrams, revision cycle, glossary, etc) which ensure that the model is described precisely. A summary of all rules can be found in in FIPS (1993).

1.2 DSM overview

The Design Structure Matrix (DSM), also known as Dependency Structure Matrix, developed by Donald Stewart in 1981 (Stewart, 1988 cited by Kamrani, 2002, p. 74) is both a system analysis tool and a project management tool. In both applications, it can be used to analyze the information flow that occurs within a system or process, identify the dependencies between tasks and sequence the development process. The DSM consists of an N x N matrix where the same tasks are listed on the x-axis and then in the same order on the y-axis. The relations between tasks are then listed in the matrix. An 'X' mark means that a relation exists between the two tasks and a blank cell means that there is no relation between the two tasks. Figure 4 shows an example of a 5 x 5 DSM. A mark in row 'i' column 'j' means that i has j as predecessor. In this way, going across the rows shows what precedes, going down the columns shows what follow. Therefore, marks below the diagonal represent feed forward and marks above the diagonal represent feedback. A summary of the different types of DSM, the data that can be represented by each DSM type and the potential uses of each type are reported in Table 1 (Browing, 2001). In our methodology the activity based DSM was used. This is typically used in project scheduling and systems analysis and allows analyzing the inputs and outputs exchanged between different business functions and activitie
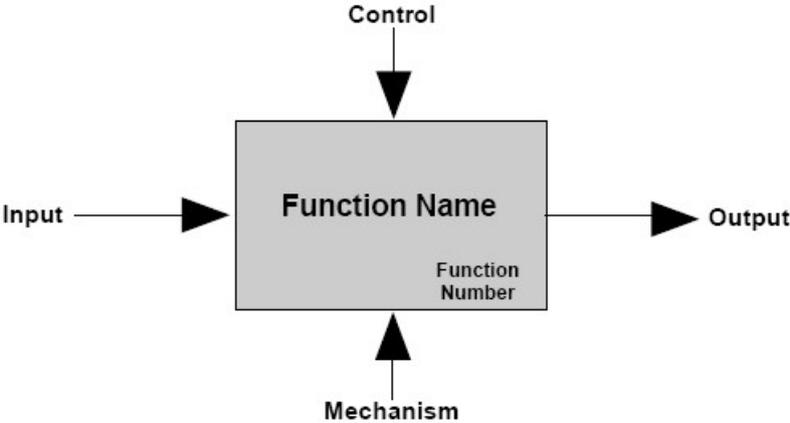
FIG. 2: Basic Syntax used in IDEF0 method
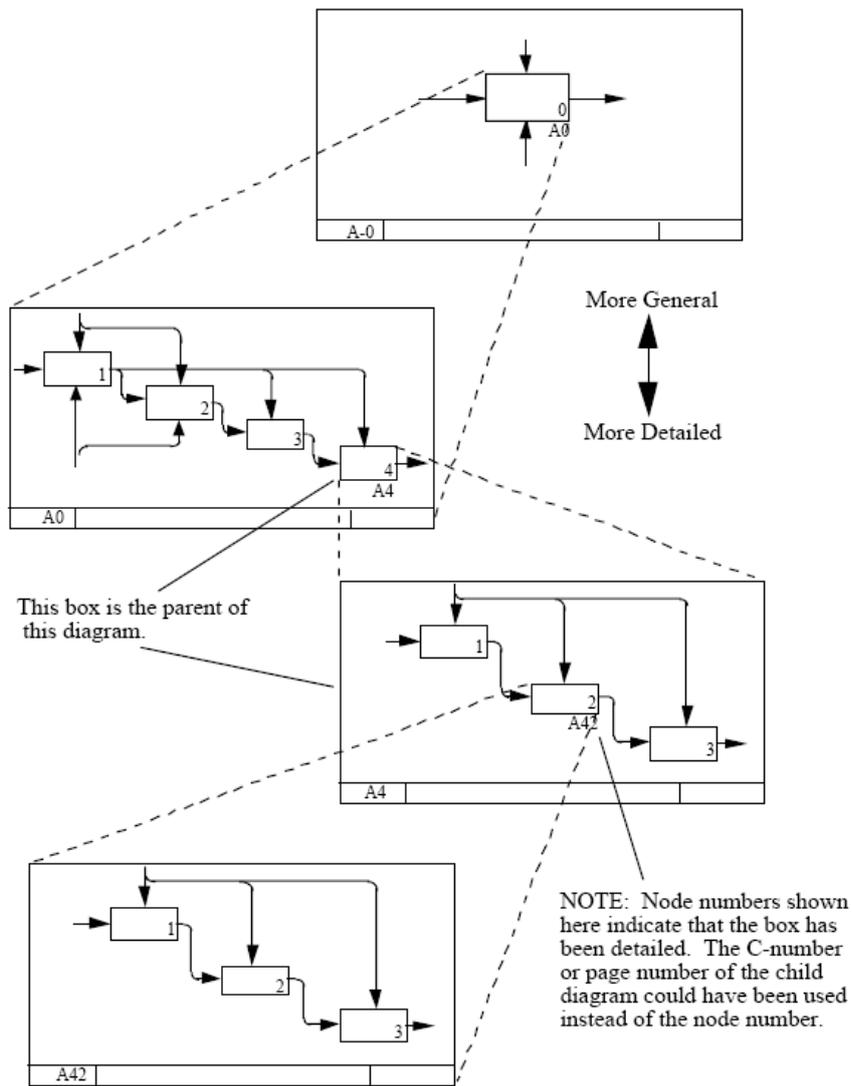
FIG. 3: Decomposition structure in IDEF0 (FIPS, 1993 and IDEF, 1993)

		A1	A2	A3	A4	A5
Prepare drawings	A1	•	X			
Approve drawings	A2	X	•		X	
Procure materials	A3	X		•		
Cut sections	A4		X	X	•	
Assemble frames	A5		X		X	•

FIG. 4: An example of an activity based DSM

TABLE 1: Different types of DSM and their applications

DSM types of DSM	data represented by each DSM type	applications of each DSM type
Team-based	Multi-team interface characteristics	Organizational design, interface management, team integration
Component-based	Multi-component relationships	System architecting, clustering, engineering and design
Activity-based	Activity input/output relationships	Project scheduling, System Analysis
Parameter-based	Input/output relations between tasks	Low level activity sequencing, Design of computational process

2. LITERATURE REVIEW

2.1 The need for Enterprise Modeling

Enterprise Modeling or business process mapping plays a major role in the perception and understanding of business processes (Vergidis, 2008). A business process is a set of coordinated tasks and activities to achieve a business objective or goal (Motahari et al., 2008). There are many definitions to business process. Since the 1990s, when the first definitions of business processes appeared in the literature, many authors attempted to focus business processes on specific directions (Vergidis, 2008). The difference between the different definitions is the degree of emphasis put on the different entities (e.g. input, output, equipments, people, effectiveness, functions, state and other attributes) involved in a business process. According to Shen et al. (2004) "a business process is a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships". A business model is often a graphical representation of the structure and operations or part of the operations of an organization. A business process is obtained through the application of suitable Enterprise Modeling techniques. In this information era, Enterprise Modeling has become a major focus of attention for the following reasons:

- The huge development of information systems to support business processes has increased the importance of Enterprise Modeling and made it necessary in any IT project for companies support. According to Shen et al. (2004), Enterprise Modeling is an initial and essential task for an IT project and this is carried out at the stage of system analysis and user requirements gathering (Shen et al., 2004). In accordance with Shen, Söderström et al. (2002) argue that business process modeling has become a major focus of attention in Information Systems Engineering, in order to create efficiency, quality and customer satisfaction (Söderström, et al., 2002);

- Process or Enterprise modeling is the backbone element in Enterprise Integration projects (i.e. increasing synergy and interoperation among people, systems and applications throughout the enterprise, including integration in manufacturing or CIM) and workflow management dealing with automation of paper and document flows as well as control of business processes (Kosanke and Nell 1997, cited in Vernadat, 2001);

- Business process mapping is extensively used in business process improvement/reengineering (Gunasekaran and Kobu, 2002), business process management (Balzarova et al., 2004), business process simulation and management of change (Chung et al., 2002). With relation to its use in business process improvement and reengineering, process mapping has proven to be a reliable way for identifying current as-is business processes (current state) and can be used to provide a to-be (future state) roadmap for reengineering the product and service business enterprise functions (Muthu, 1999);

- There is an increasing shift from the traditional way of organizing companies in separated departments (called silos) to process orientation. Enterprise modeling can provide a better understanding of existing processes and help companies in the migration from departmentalized organization to process orientation.

The selection of the right technique is one of the essential steps in an Enterprise Modeling project as it can substantially undermine the chances for success. Before analyzing the criteria for the selection of the right modeling technique for the task, a general overview of existing modeling techniques is indispensable.

2.2 Existing Enterprise Modeling methods

There is an abundance of Enterprise Modeling methods. Each modeling technique captures different aspects of a business process and having distinctive advantages and disadvantages. Shen et al. (2004) ranked business process modeling techniques into 3 levels (Figure 5):

- **Enterprise Modeling frameworks:** This level contains methodologies to guide the system analysis and design for the whole life cycle. Among the most used methods at this level are CIMOSA (Computer Integrated Manufacturing Open System Reference Architecture), GIM (Groupe de Recherche Architecture et Infrastructures) and PERA (Purdue Enterprise Reference Architecture). CIMOSA is an Enterprise Modeling framework, which aims to support the enterprise integration of machines, computers and people. The framework is based on the system life cycle concept, and offers a modeling language, methodology and supporting technology to support these goals.

- **General system modeling methodologies:** This level includes both structured methodologies such as Structured Analysis and Design Techniques (SADT) and Object Oriented (O-O) methodologies such Unified Modeling Language (UML). SADT has been in place since decades and provide a specific functional view of any enterprise by describing the functions and their relationships in a organization. O-O methodologies have grown in importance over the last two decades due to their suitability in software development projects. One of the most used O-O methodologies is the Unified Modeling Language (UML). It contains a set of symbols (the notation) and a group of rules (semantics) that manage the language (Noran, 2000, p.12) and it is mainly used for software development. UML models are complex due to the large number of diagram types and are often difficult for end users to understand and therefore, it can be inappropriate to use during the stage of conceptual modeling and end user requirements gathering (Shen et al., 2004);

- **Particular modeling methods for individual views:** there are four views; the functional, the informational, the organizational, and the decision view (Figure 5). For each view, there are a number of modeling techniques that support its objectives. Some of these techniques are later discussed in the paper.

A more detailed description of all these methodologies can be found in Shen et al. (2004). Another review of modeling techniques is that presented by Aguilar-Savén (2004). Modeling techniques were classified on the basis of two dimensions (Figure 6):

- **The purpose of the model:** can be descriptive for learning, decision support for process design, decision support for process execution and IT enactment support;

- **The model change permissiveness:** This characteristic pays attention to the level of changes that modeling methods can allow and facilitate. Modeling techniques can allow either an active or passive degree of permissiveness. Active modeling techniques allow users to make changes whereas passive techniques do not allow users to make changes without remodeling the process.

According to this classification framework, the modeling methods are plotted into a two dimension graph (Figure 6). In terms of the modeling purpose of the different methods, Aguilar Savén's classification is not very different from Shen et al.'s classification. However, it adds the dimension of the modeling methods behavior in terms of allowing and facilitating models change.

2.3 Guidelines for the selection of the right modeling method

The selection of the right technique is an essential step in an Enterprise Modeling project as it can substantially undermine the chances for success. According to Shen et al. (2004), the selection of modeling method depends and should vary with the project requirements, as well as with the implementation scenario. For example, in the development of management implementation systems, it is important to employ a modeling method that is understandable and unambiguous to both end users and developers. In addition, at the initial stages of the development process of management information systems, a structured method for the system analysis is the best method during for the system analysis and user requirement gathering. The classification presented by Shen et al. (2004) helps in understanding the selection as a function of the view to be modeled. However, the guidelines given by Shen et al. would not be sufficient to enabling the selection of an accurate modeling method for the task as the selection depends on a wider number of issues related to the purpose of modeling, the environment and the characteristics of the modeling method itself.

The classification and framework presented by Aguilar-Savén (2004), compared to that presented by Shen et al. (2004), sheds light on the purpose of the model and its behavior with regard to change. The two classifications and frameworks can complement each other. However, both frameworks do not still clarify the problem of the selection of the right modeling technique as they ignore many attributes related to the practical perspective of selecting a modeling technique and to the environment to be modeled.

Bider (2005) recognizes that there is no universal method of business process modeling suitable for all possible projects and the selection of the appropriate method should be done on the basis of three dimensions:
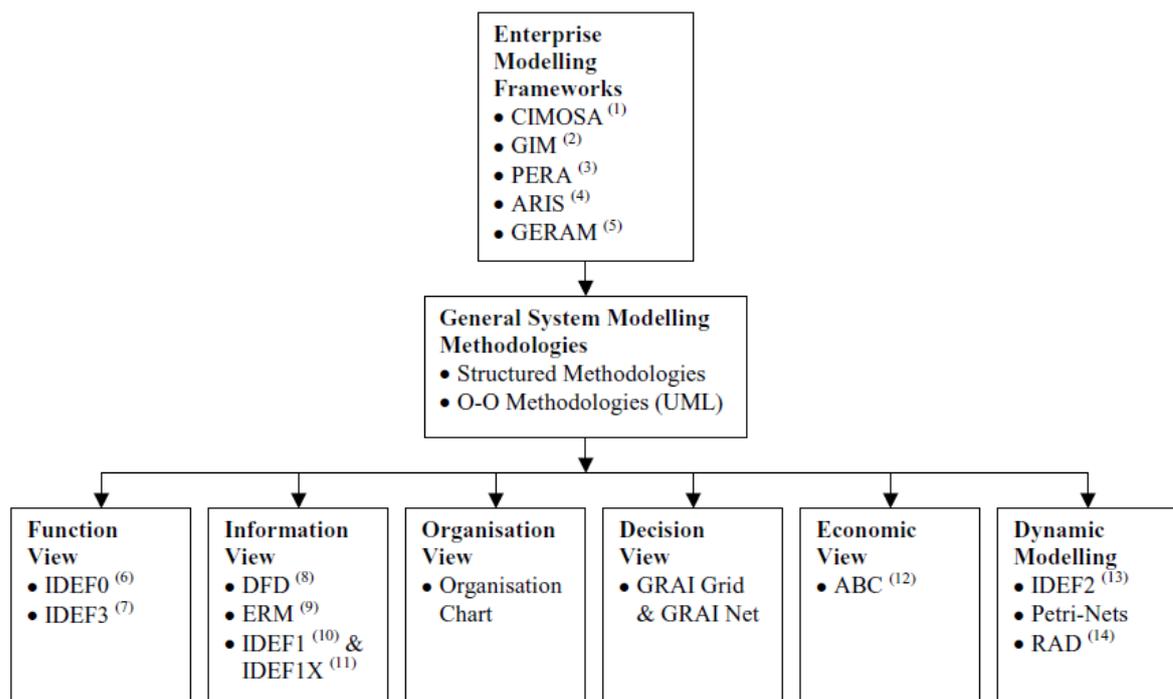

FIG. 5: Classification of modeling methods and techniques (Shen et al., 2004)
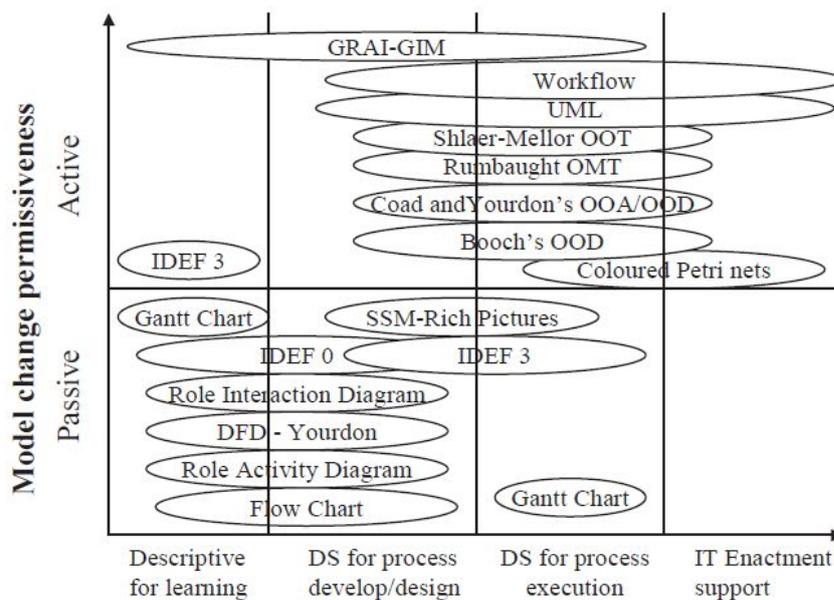
FIG. 6: Classification of business modeling techniques by Aguilar-Savén (2004)

- Properties of business process to be modeled: these include the degree of physicalness and mobility of passive participants (e.g. documents, drawing, car being assembled) the level of specialization and degree of mobility of active participants (e.g. people and equipments), the degree of precision of operational goals, the autonomy and characteristics of the process environment, the nature of activities and the orderliness of process flow;

- Characteristics of the modeling environment: these include the level of process maturity in the organization, and the professional background of human participants;

- Intended use of the model: it can be for increasing process maturity (e.g. make the staff and process conscious, improve cooperation, educate new employees), analysis and reengineering (e.g. quantitative and performance analysis, or qualitative), and building computer systems.

Although the framework presented by Bider (2005) introduced a new set of variables relevant to the problem of the selection of the modeling technique, it still lacks of a method that takes into consideration all these variables. In fact, Bider (2005) aimed at shedding light on some practical perspectives and at stimulating researchers to pay more attention to the practitioners needs, rather than presenting a unique solution to the problem of the selection of the modeling technique. The selection examples given by Bider were performed as a function of only some of the variables mentioned. For example, according to Bider, if an organization is functionally structured and processes are not identified, Bider (2005) recommends the use of an input/output view (e.g. IDEF0) or an agent-related view (e.g. RAD). In addition, the input/output flow is recommended when the focus is on the passive participants that are being consumed, produced and changed by the activity and there is a need to ensure that each passive participant has undergone a specified number of operations. Who does the operation has less importance. In such a case, Bider recommends methods like IDEF0. When the focus is on agent cooperation (i.e. order in which active participants perform their job) and it is important to ensure that each active participant is doing his part of job, Bider (2005) recommends an agent-related method like RAD (Role Activity Diagram).

From this review, it can be concluded that researchers do not agree on a framework and do not present clear guidelines for the selection of the modeling technique. However, after the analysis of the existing state of art, it can be claimed that in order to select the most suitable technique for a specific Enterprise Modeling project, all the following four main attributes should be taken into consideration: the purpose of modeling, the ease of communication between end users and system developers, the characteristic of the modeling environment and the characteristic of the modeling technique itself. The application of these guidelines are shown later in the methodology once background information for the case study has been presented.

3. CASE BACKGROUND

The organization, where the case study was conducted, is a British organization involved in a cross-functional business which entails a wide range of activities going from manufacturing to construction. The organization operates for main construction contractors as a fist-tier sub contractor in the design, manufacture and installation of building envelope elements including curtain wall and other building façade products. In order to successfully deliver projects in such a business sector, the organization has to deal with a greater number of activities, operational difficulties (e.g. estimation and tendering, simultaneous multi-site installations, planning and coordination of manufacturing and deliveries for a number of sites) and stakeholders (e.g. contractors, subcontractors, architects, suppliers) compared to companies involved in more homogeneous sectors. Over the last five years, the organization has been growing in terms of turnover, size of projects awarded, business premise, and personnel. This growth has been accompanied by a growing difficulty in the coordination and lack of information exchange between the different departments internally and with the external stakeholders. This has been causing many operational problems and delays. To deal with this problem, the organization required analyzing the entire business process by investigating all functions, interdependencies and the information flow. This analysis should lead to the identification of all important information that must be shared between internal departments and the external environment to enhance coordination and integration. The sharing of information is then enabled by the implementation of a web based collaborative software tool. Therefore, the main two objectives of this Enterprise Modeling case study are:

- To model the entire business process (called as project delivery process) by identifying the information flow and the inter dependency between the activities making part of this business process;

- To define the requirements for a web based collaborative working software tool which should provide the right information at the right time for both internal and external stakeholders.

4. METHODOLGY

The methodology proposed for Enterprise Modeling is depicted in Figure 7. The objectives are to model the entire operation of the business and to then define the functional requirements for a collaborative working software tool. As part of this case study, the authors will apply the guidelines for the selection of the right modeling technique. In accordance with the guidelines presented earlier by the authors for the selection of the modeling techniques, the modeling technique should be selected as a function of the following four attributes: the purpose of modeling, the ease of communication between stakeholders, the characteristic of the modeling environment and characteristic of the modeling technique itself. For this case study, available modeling tools were checked against these criteria as follows:

- **The purpose of modeling:** the authors intend analyzing the entire business process of the organization and then define the functional requirements for a new management information system. For such a purpose, the literature suggests that the best method to choose should be based on a structured analysis. Morris et al. (1990) suggests that structured methods (e.g. IDEF) are very used in industrial information systems to define the user needs for IT development. Shen et al. (2004) argue that for the stage of system analysis and user requirements gathering, a structured methodology is still irreplaceable (Shen et al., 2004). In addition, Shen et al. (2004) findings, based on a wide review of relevant documents and software, as well as the criteria for tool selection, were that IDEF0, IDEF3 and DFD are currently the most suitable methods for business process modeling in IT projects. With relation to system analysis, IDEF0 has proven to be one of the most used technique in the stage of system analysis and user requirements gathering (Lindfors, 2000; Shen et al, 2004). Also the framework presented by Aguilar-Savén (2004) suggest IDEF0 as one of the modeling techniques to be used in situation such as process analysis and requirements gathering;

- **The ease of communication between stakeholders:** Traditionally business analysts have had difficulties in capturing 'as-is' models of business in order to better understand and subsequently improve them. For this reason, it is very important that the technique used is understandable and

unambiguous to all stakeholders (e.g. end-users and system developers in the case of MIS projects). To highlight this aspect, Vergidis (2008) argues that a business process is as expressive and as communicative as is the technique that has been used to model it (Vergidis,2008). Also with regards to communication, structured methods have proven to be the easiest techniques for communication between end users and system developers. For example, Shen et al. (2004) compared other modeling methods such as Petri-Nets and RAD with IDEF0/IDEF3/DFD, and found out that even though they are also widely used, they are not as understandable as the latter three when discussing with end-users. A pilot test and a survey conducted to gauge the response of workers in terms of how readily they were able to understand the contents of a quality manual written in both a conventional language (texts) and the IDEF0 format showed that around 70 per cent of the subjects reporting high efficiency, clarity and legibility of the quality manual writing using the IDEF0 format (Lo et al., 201);

- **The characteristic of the modeling environment (business process):** the business environment of the organization is characterized by departmentalized divisions (i.e. finance, commercial, design, procurement, production, installation, site installation, and project management) in which processes are not totally identified. The environment is collaborative and formal ways of communication internally and externally via objects like documents and files are in place. For such an environment, Bider (2005) argues that it is suitable to use an input/output view (e.g. IDEF0). In addition, a functional organization can be best described by a structured modeling technique such as IDEF0, which can depict these functions and the data associated with them in order to illustrate clearly the as-is situation;

- **The characteristic of the modeling technique itself:** In order to analyze this aspect, a deeper insight about the features of modeling techniques and a comparison among them is necessary. Even the selection has been already narrowed down to structured modeling techniques (i.e. IDEF0, IDEF3) and techniques such as DFD (Data Flow Diagram), a complete comparison of most used techniques can be useful not only for the final selection but also for the understanding of what the other techniques can offer. In addition, this is also important as modeling techniques can often be used in combination to provide better modeling. A comparison of the most used techniques can be found in Aguilar-Savén (2004). This comparison shows that the IDEF0 can model a wider range of entities compared to the IDEF3 and the DFD. Whereas the DFD (Data Flow Diagram) shows only the data flow, the IDEF0 allow the modeling of the flows of activities, inputs, outputs, control and mechanisms. Compared with the IDEF3, the IDEF0 allows quick mapping and can be used to build software by developers. However, while IDEF3 represents the precedence relationship between activities (i.e. behavioral aspects of a system), the IDEF0 does not and has the disadvantage to be often interpreted as a sequence of activities. Another comparison between the IDEF0, IDEF3, and DFD is presented in table 2. This table shows that while the IDEF0 compared to the DFD and IDEF3 offers the best suitable structure for the decomposition of a business model into lower levels of detail, it is the most difficult to create, lacks of sequential representation and has poor logical representation. However, this project is more concerned with modeling the entire business process of the organization and capturing the functional requirements and information to be shared between stakeholders rather than the sequential representation.

From the analysis of the current project objectives and after checking existing modeling techniques against the above four criteria, there is no doubt that the most suitable modeling technique for such projects is the IDEF0. In fact, as stated in the introduction, the scope of the project is to identify and model all functions and activities which occur during the "project delivery process" and associated information (i.e. the input to each activity, the output, what resources and controls are used) and then identify the functional requirements of a web based collaborative working software tool. The only technique able to represent this variety of information is the IDEF0. However, for a large process like the "project delivery process", the authors are concerned about the difficulty in identifying the interaction between the different processes making part of the "project delivery process". In fact, with the IDEF0, due to the multitude of levels and hierarchy nature of diagrams, interactions and feedback loops are difficult to follow. For this reason, the author found out that if the IDEF0 is used in

combination with the DSM (Dependency Structure Matrix), not only can overcome this limitation but also provides other advantages in analyzing the as-is process and communicating the interactions between activities to the system developers. There are many features which make the IDEF0 and the DSM complementary tools for this work. . While the DSM focus only on inputs and outputs of each activity, the IDEF0 gives also information about the controls and mechanisms (resources) used to perform each activity. For example, if the DSM is only used and an activity requires a control from another department to be accessed, this information can be easily missed as it is not reported in the DSM. However, if the IDEF0 box for this activity is checked, this requirement can be easily noticed and taken into consideration. A complete list of the reasons that show why IDEF0 and DSM can be used as complementary tools is provided in table 3.

5. CASE STUDY

The purpose of the Enterprise Modeling work in this case study is to model the entire operation of a British organization involved in the construction supply chain as a designer, manufacturer and installer of building envelope elements (Façade industry) and then capture the functional requirements for a web based collaborative working software. To achieve this aim, the objective of this study is to model all the organization's activities involved in the delivery of a typical project. Therefore, the focus of Enterprise Modeling is on process modeling rather than data modeling. The process considered is called as "project delivery process" and it involves all activities related to the following main business functions: sales and estimation, commercial, design, procurement, production, project management and site installation.

Although a series of Business Process Reengineering (BPR) actions were undertaken after mapping the current state (as-is) in order to take into consideration future business requirements and eliminate current inconsistencies, these were not reported in the methodology depicted in Figure 7 as they are beyond the scope of this paper. All stages of the case study were performed as described in the following sections:
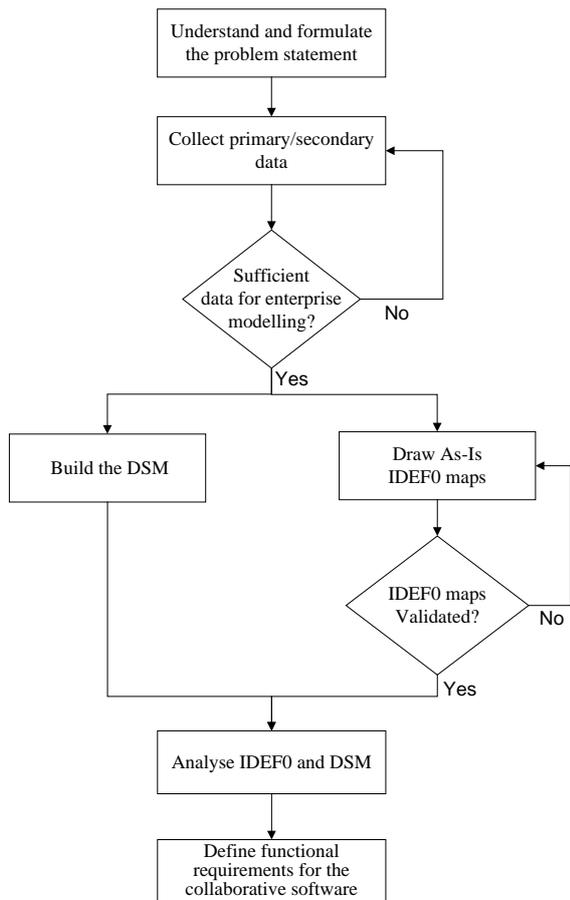
FIG. 7: Main steps of the methodology

TABLE 3: Comparison of the attributes of IDEF0, IDEF3, and DFD (Shen et al., 2004)

	Structure	Ease of creation	Strictness of syntax/semantic rules	Information expression	Sequential expression	Logical expression
IDEF0	Can be decomposed to lower levels in a straightforward manner (1)	Detailed models at an early stage are difficult to create (3)	Very strict syntax. Only two types of graphical notation means that strict rules must be applied (1)	Good at representing information but has no data storage notation (2)	Poor sequential representation (3)	Poor logical representation (3)
IDEF3	Can be decomposed but not as straight-forward as IDEF0 (2)	Intuitive and easy to understand. Can be easier to create (1)	Least strict of the three methods. Four types of notation allowing more flexibility of representation (3)	Not a strength of IDEF3. No data storage notation (3)	Excellent for representing the sequence of a process (1)	Excellent logical representation through the use of logic junctions (1)
DFD	Can be decomposed but not as straight-forward as IDEF0 (2)	Intuitive to a degree. More abstract than IDEF3 (2)	Less strict than IDEF0 but allowing flexibility of expression through variety of graphical notation (2)	This is the strength of DFD. Provides notation for data storage (1)	It is possible to deduce the sequence of a process using some DFDs (2)	Poor logical representation (3)

1: best, 2: medium, 3: worst.

TABLE 4: Complementary features of IDEF0 and DSM

IDEF0	DSM
Suitable where there is demand on strong formalism about the structure and semantic of the information (e.g. a computer support system for the information management process)	It provides information only about the input/output of each activity (it indicates that there is a relationship between 2 activities)
Information mapped include: inputs, outputs, mechanisms and controls of each activity. 1	Even information can be detailed to include the kind of information; this is often avoided as it makes complex the analysis of the matrix
It provides a clear vision and distinction between processes and sub-processes	It does not distinguish between processes and sub-processes. For each process or sub process, a row in the matrix is assigned
It does not capture informal communication	Informal communication can be represented
The model complexity grows relatively with large process to model	It can be applied on large problems while maintaining good overview of the model
Iterations and feedback loops are hard to follow due to the multitude of relations and the hierarchy of the model	Iterations between activities can be easily shown

5.1 Understanding and formulating the problem statement

This stage is of crucial importance to the success of the project as it allows not only the understanding of the problem but also influences the selection of the tools (modeling techniques, tools for information collection) to be used in the following stages of the project. This stage lasted for three weeks and was performed through the following actions:

- Meeting with the organization's board and line managers: It was necessary to take part to meetings with the board and line manager. These meeting were used to analyze the overall performance of the organization, review of what has been achieved in terms of actual improvements versus planned objectives and plan the future actions. These meeting allowed the authors to have deep insights into the operational difficulties and coordination issues the organization has been facing;

- Informal meetings with staff members working on processes: These were unscheduled and were used to understand the difficulties affecting the operation and to collect information about the business process;

- Observing the real process in action: It was opted to observe the real process in action in the coordination department. This allowed to understand a large part of the organization's operation and associated problems.

The above actions allowed a full understanding of the nature of communication and coordination problems. The main conclusion was that the lack of right information at the right place and at the right time was mainly due to an inadequate IT support system rather than the availability of the information itself. The current system based on shared folders on a central server did not allow easy access, updates and sharing of information.

5.2 Data collection

Data were collected from both primary and secondary data sources. Secondary data is information that already exists in some form. Generally, these forms include the available literature, previous studies and existing organization's documentations. Primary data is data that is not available in existing written documents and collected by questionnaires and interviews. The decision was to first explore secondary sources and then collect primary data. This helps in targeting the right type of information and avoids duplication in collecting the information, thus enhancing the efficiency of this stage and the overall quality of the information collected.

The secondary data was collected from existing organization's documentations. In particular, the quality procedures and manuals as they contain an extensive description of the operation and processes and from the meeting minutes of previous workshops and review meetings.

The primary data was collected by conducting semi-structured interviews with process experts from all

departments. First, a list of process experts (managers) and clerks were identified with the help of the organization's operation director. The idea of interviewing both managers and clerks is due to the fact that they can have different views about the operations. Small operational details may be easily overlooked by senior managers while they can be accounted for by clerks who deal with these details on a daily basis. Fourteen staff members from six different departments were interviewed (i.e. sales and commercial, procurement, design, manufacturing, site and project management and coordination) and seven detailed interview guides were designed carefully and tailored for each process. These guides were also sent to interviewees four days before each interview scheduled time. An overview of the type of information collected by the semi-structured interviews from the different departments can be summarized by the following macro entries:

- Main activities performed in each department;
- Sub-activities related to every main activity;
- Main deliverables and outputs of activity and department;
- Recipient or customer of each deliverable and outputs (e.g. internal such as another department or external such as client or suppliers);
- Associated documents with each deliverable and their formats;
- Means of communication and transferring of each deliverable (e.g. email, web based information management system, central shared server folders, hard copies, etc.);
- Information required to produce each deliverable (e.g. drawing or plan), the information providers (e.g. another department or client) and the means of communication and transferring of the information;
- Other information: key performance indicators used in each department, most performed activities, main difficulties, software tools used and suggestions for improvements.

Immediately after the semi-structured questionnaires were collected and interviews were conducted, the answers were analyzed and compared. New enquiries were made to both find missing information and ask clarification about the answers, whenever was necessary. Once all information was complete and clear, this was structured in an appropriate way to suit IDEF0 modeling.

5.3 Building IDEF0 maps

The "project delivery process", subject of modeling, involves all activities related to the following main business processes: sales and estimation, commercial, design, procurement, production, project management and installation at site. The important decision made by the authors is to draw all those processes under the same context diagram (A-0 box) named "deliver project". This helps focusing on the interactions and information exchanged between the different processes and activities.

The IDEF0 technique places strict syntax and rules on the modeler. While this provides rigorous and concise models, this makes IDEF0 diagrams one of the most difficult diagrams to draw. One of the biggest difficulties in modeling with IDEF0 is to control the level of detail that constrains the creation of the model. For this aim, the context diagram (A-0 box called in IDEF0) should clearly state the viewpoint and purpose of modeling. The purpose of modeling must always be borne in mind while modeling in order to avoid loading models with unnecessary details.

The context diagram for this case study is illustrated in Figure 8. Figure 8 shows that the final aim of this business process is to perform the installation and handover of projects to clients, receive the money and release eventual money retention. The main inputs to this process are the clients and contractors' enquiries and tenders. In addition, they are many other inputs that cannot be reported at this level and they are reported in the following high detail level diagrams and depicted with tunneled arrows at their unconnected ends. The process in A-0 diagram (Figure 8) is governed by controls such as the organization's business strategy and management expertise, the awarding criteria, the source of lead and the client and site requirements. To perform this process, the necessary mechanisms include human resources which are the organization department's staff (sales, commercial, design, procurement, production, site staff and project managers), software tools and equipments.

The A-0 context diagram was then decomposed into higher levels of details (A0, A1, A11, A12, … , A61) to include all main processes and activities performed during the delivery and control of projects. These high detail

level diagrams, in accordance with the IDEF0's syntax, are numbered according to the box from which they originate. The number placed in the bottom right corner designates the sequence of breaking down the different boxes and the unique identifier shown under the bottom right corner of each map designates the map reference where the box is decomposed. The reference in the bottom left corner of each diagram (e.g. A0) is a unique identifier that expresses the relationship between parent and child diagrams.

The main sub-processes and activities that make part of the "project delivery process" are reported in the diagram A0 (first diagram that follow A-0) shown in Figure 9 in six different boxes (i.e. sales and estimate, plan and follow up commercial activities, design, procure material, manufacture goods). In this diagram the information transfer and interactions between these six sub-processes can also be identified. For example, from Figure 9, it is clear that information such as ultraviolet values, thermal calculations, barrier loading, and acoustic rating are required as input to both the sales and estimation and the design process. However, not all interactions and information can be reported at this stage. In fact, it is necessary to decompose each of these six processes into greater level of detail each in order to understand and explore more in depth the interactions between them. Therefore, these sub-processes had been further decomposed and the reference to their decomposition diagrams is reported beneath the lower right corner of each box (MK3, MK7, MK11, MK16, MK20, .., MK31). 31 maps were built to decompose the project delivery process to the level of detail required. For the purpose of this paper, only some diagrams (i.e. sales and estimation) can be shown.

The sales and estimation process (diagram A1) is shown Figure 10 and the decomposition of its box "2" (estimate) is shown in diagram A21 in Figure 11. Figure 10 shows that the main sub-processes of the sales and estimation process are: the decision about tendering, the estimation and tender submission, and the post-tender follow-up activities. A part of the interactions and information exchanged between these three sub-processes and the external environment can be seen in this diagram (Figure 10). If the decision is to present a bid then, the estimation process should lead to the final tender submission. This stage is described in Figure 11 which shows that the estimation process includes the following activities: the procurement of full enquiries from client and contractor, the summary of scope of work in a sketch, the analysis of the scope of work, the request for quotation from procurement, the addition of other costs and the final preparation of tender analysis summary sheet. It can be clearly seen that many of these activities require interactions and inputs from client, suppliers and other departments. For example, while estimating the elements of the scope of work:

- The ultraviolet values, the thermal calculations, the barrier loading, and acoustic rating are required from suppliers;
- Quotations should be provided by the procurement department for special elements (e.g. special glass, revolving door)
- Inputs are required from design, operation and manufacturing departments about their program costs;

At the end of this sub-process, the tender package is submitted (Figure 11) using the available standard forms (standard forms QP.01.SD6 and QP.01.SD7.1 to QP.01.SD7.9) and the green sheet (standard form QP.01.SD3) is finally signed by the managing director (table 4).

The entire IDEF0 model for the project delivery process was decomposed into 31 maps. In conjunction of many nodes there are some key words and acronyms that require further explanation. Those words were noted by the symbol "*" and their explanation is given in the glossary in an alphabetical order. This is the only exception to the IDEF0 rules. According to IDEF0 rules, the glossary requires a specific reference to be attached to the node. Table 4 represents a small section of the glossary which explains the key words and acronyms that appeared in the maps presented in this paper.

The validation of the maps was performed by adopting the reader-author cycle critique procedures in accordance with IDEF0's rules every time a set of maps were produced.

5.4 Building the DSM

The multitude of levels in IDEF0 and the hierarchy nature of diagrams make interactions and feedback loops difficult to follow and understand. In addition much information (e.g. informal communication and activities), that were collected by the semi structured questionnaires and interviews, although they are relevant for the

enterprise modeling exercise and the definition of requirements for the collaborative working software tool, they cannot be represented by the IDEF0 technique. A summary of the reasons for using the DSM in combination with the IDEF0 were illustrated earlier in table 3. An important benefit from using the DSM is to focus on the inputs and outputs required for each activity and to help in defining the access and permission policy to different folders and documents shared by the collaborative software tool ("who can access what").
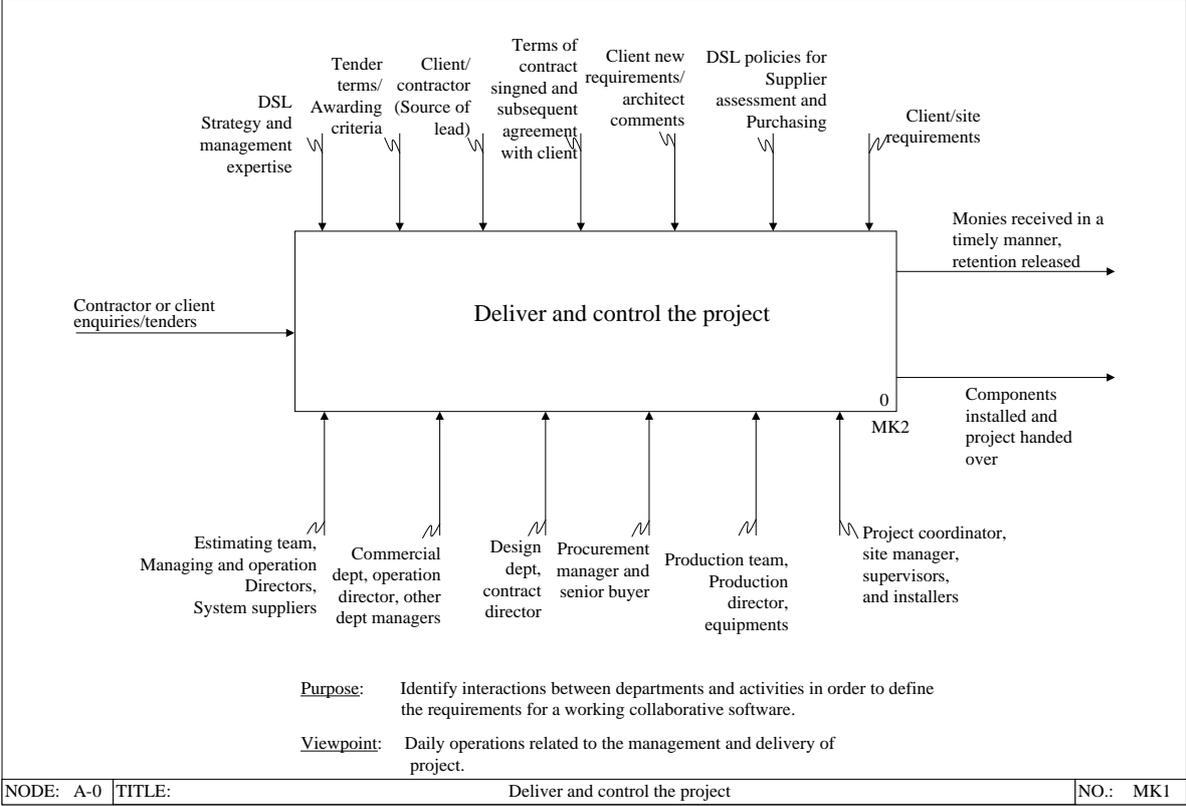
FIG. 8: The context diagram A-0 for the project delivery and control process

Table 5: A section of the glossary for the key words and acronyms

Agreed action	Tender, decline, or request extension/further details and advise client
TASS	Tender Analysis summary sheet: a document that summaries clearly the scope of work
Estimation Checklist (QP.01.SD2) or Green Sheet	A spreadsheet which contain details of contractors/architect and a checklist of steps to carry out before tender submission.
MTO and Drawings	Material to order. Drawings include passport, approval drawing, scope of work, fabrication drawings, cutting list, and construction drawings
Cutting Lists	They are drawings (optimization sheets) reporting lengths at which sections should be cut and the codes of preps to identify in system manuals and then program the NC code to machine the preps on CNC
Forms QP.01.SD6 and QP.01.SD7.1 to QP.01.SD7.9	QP.01.SD6 is the standard form to submit the economic tender, the other form QP.01.SD7.1 to QP.01.SD7.9 are standard form to attach documents related to H&S, Environmental and control policies, method statement, maintenance manual, and program
QA Sheet (QP.05.SD1 and 2)	They are checklist for quality assurance for all operation required on the shop floor

Quality Sheet (QP.05.SD4)	A quality necessary to assure that the right material are issued to the shop floor. It is a checklist regarding the correct length, off cuts, section, and color

To build the DSM, the authors used the information identified and structured before drawing the IDEF0 diagrams for the project delivery process, the IDEF0 diagrams and other information collected but not used in the IDEF0 diagrams. This provided an exhaustive list of the activities involved in the project delivery process and a rapid building of the DSM. The complete list of activities were listed on the x-axis and then in the same order on the y-axis of the DSM and were grouped by department. A mark (x) in row i and column j (elemet ij of the matrix) means that the activity i requires an input for activity j (i.e. the output of activity j). For this reason, in addition to the activity list, the outputs were listed on the y axis (first column). The resulting DSM matrix is a (105x105) matrix. Figure 12 shows only a portion of the matrix (many lines and columns between 1 and 105 are hidden). The authors filled the matrix themselves based on their understanding of processes gained while collecting information and drawing the IDEF0 maps and then submitted the matrix to process experts who were asked to fill out the portion of the DSM related to their process (e.g. the sales and estimation was asked to fill out from line 1 to line 18). This also helped in making staff members aware of all information and documents available in other departments so they can make decision about either sharing or having access rights to such information and documents. A column called "notes", not shown in Figure 12, was added as the last DSM column at the right to show important information such as: the standards forms used for some activities, the logic or rules adopted in some operation (e.g. the architect should give a feedback on drawings within ten working days) and some other important information relevant to the collaborative working software tool.

5.5 Definition of requirements for the collaborative working software tool

To test and validate the effectiveness of the Enterprise Modeling methodology presented in this paper, the authors opted to use the enterprise models and the dependency structure matrix for the definition of functional requirements and folders' content of a web based collaborative software. The traditional method used by most information systems specialists is to conduct interviews with process experts to capture those requirements. Using interviews only, there is a risk that important requirements may be overlooked. By using the enterprise models built using the presented methodology, none of the important requirement could be missed.

The collaborative working software tool has the objectives of improving the communication and enhancing the coordination internally, between the organization's departments and externally, with the construction site and external stakeholders. The IDEF0 maps and the DSM matrix formed a good basis for the definition of requirements for the collaborative software. However, the definition of requirements from the IFEF0 maps and the DSM is not an easy task. It requires a thorough analysis of the IDEF0 maps and the DSM. The involvement and suggestions of staff members (end users) is crucial for the validation of the requirements. For this reason, all process experts and key staff members were involved all the way through the project:

- First, staff members were interviewed during the stage of information collection before modeling and then for the validation of models (IDEF0 diagrams and the DSM);
- Second, staff members were asked to fill out the DSM's section relevant to their processes in order to identify which information is required to fulfill each activity they are responsible for;
- Third and most importantly, after an initial set of requirements were proposed by the authors based on the analysis of the IDEF0 maps and the DSM, staff members were asked to consider also non existing documents that if introduced and shared with other staff members, many non value added activities (e.g. dropping in offices, phoning and chasing) can be eliminated.

At the end of this process of analyzing the enterprise models and involving staff members, a clear set of functional requirements were identified for the collaborative working software tool. These requirements were communicated and discussed with the information system specialist who was able to clearly understand the business needs, structure the layout of the software and give some suggestions to deal with some technical issues (e.g. automatic notification, user friendliness, lean flow of information).

*Fig. 9 The decomposition of the project delivery and control process*

FIG. 10: Level A1 of the sales and estimation process

FIG. 11: Level A12 mapping the estimation sub-process

Output	Activity	#
Enquiry Identified	Identify enquiry within tender database*	1
Estimation Checklist initiated (source of lead, value)	Create estimation checklist	2
Letter of interest sent	Send a letter of interest if required	3
Important info added to checklist	Add important info tochecklist*	4
Tendering/other action agreed*	Decide if tendering/other action	5
Full enquiry receipt	Procure required info from client/contractor*	6
BoQ for pricing	Summarise Scope in sketch	7
Elements of scope estimated	Estimate elements of scope	8
historical data compiled	compile historical data to assist in future tender	18
Contract reviewed	Check order before handover	19
Lead designer,site manager , and proj. Coordinator	Meet for handover;	20
Final contract docs signed	Sign Docs and acknowledge receipt of order	21
Contract scope of work agreed. Valuation breakdown	Issue and agree valuation breakdown	22
Sub-contract tenders issued	Issue subcontracts enquiries to suitable comp.	23
Sub-contract order signed by both parties	Benchmark and appoint subcontractors	24
Sales and value report to accounts and mangt	Produce internal valuation analysis and sales report	30
Subcontractor paid. Subcontractors liability analysed	Analyse and certify sub-contractor apps for payment	31
Info and drawing receipt	Procure info from client/architect	32
Project checked	Check the project against legislation/guidlines*	33
Action programme*. Design Programme*	Agree action and design program	34
SoW drawings issued for approval	Produce scope of work drawings*	35
SoW drawings approved	Approve drawings by architect	36
Material specifications	Select and specify material	37
Drawing register (QP.02.SD7)*. Incoming drawing filed	Log and file incoming drawings	45
Outgoing drawing logged on Drawing register and issue	Log and file outgoing drawings	46
correspondences (mail, fax) filed in the central project	Record correspondences	47
Answered TQ date is logged on the front register sheet.	Record TQ	48
Lesson learnt and performance assessed	held final meeting to asses result	49
Approved suppliers list (QP.04.SD12)	Evaluate new suppliers	50
Quotes submitted	Ask quotes from prospective suppliers	51
Supplier selected, Bid tab* filled for glass, Quotes for	Compare suppliers' offers	52
POs placed for general items, glass, sections and panel.	Raise Pos to approved suppliers	53
Delay notice, order confirmed	Monitor variations/confirm order	54
goods received in DSL or at site (supplier delivery note	Receive materials	55
Feedback report on suppliers. Approved supplier list	Monitor and Reevalute suppliers	62
Non conforming material identified*.	Unload and check material in	63
Delivery note initialled for conforming materials	Cross check with procurement agianst PO	64
Passed material stored on non return racks	Store passed materials	65
Non conformance report raised (QP.05.SD3*)	Issue non conformance report to procurement	66
Non conf materials identified with sticker and stored on	Identify and store non conforming materials	67
Requisition sheet (QP.05.SD7) added to Quality	Cross check with requisition sheet and QA sheet no 4*	68
Sections cut and identified	Cut and identify sections	69
Timber pallets	Manufacture timber pallets	79
frames stacked on timber pallets and loaded	Load/palletise finished goods	80
GDN issued logged on Good Despatch register. Goods	issue GDN (QP.05.SD10)	81
Manufacturing plan	Forcast manufacturing hours per contract	82
Installation programme	Agree installation programme	83
Site set up requirements (welfare, accodomation,	Pre start meeting with client	84
Methods statement and access statement, CSCS	prepare methods statement, access statement, CSCS	85
Risk assessment	assess site risks	86
tolerance verified: site opening, frames, and	check site openings and frame components, and	87
Weekly site report (programme slippage, material	Produce weekly site report	91
Hand over documentation (QP.06.SD4.1 to	Install and hand over items	92
Recommendation (new materials, new methods)	Learn from experience	93
Project program and component tracking sheet	Gather information from other depts.	94
Project master plan (QP.06.SD.8)	Prepare project master plan	95
Project schedule updated	Track project	96
Hour's sheet (QP.06.SD6)	Allocate time to specific task	97
Incoming correspondences are recorded in the Contract	Record incoming correspondences	98
O & M manual (QP.01.SD7.5) sent to client	Liaise with design to send the O & M manual to client	104
Company performance assessed (program, lesson	Held post project meeting	105

FIG. 12: The DSM matrix for the project delivery process

From a comparison between the requirements identified using the presented methodology and those defined by a consultant, who had gathered the requirements from interviews with staff members, it was found out that about twenty important requirements were missed by the consultant. Once all requirements were agreed by the organization and the information system specialist, these were clustered into three main categories according to their characteristic: Standard or static documents (e.g standard forms for quality assurance) that are usually used in all projects; dynamic documents that are project specific and vary across projects (e.g. different drawings, programs, site reports, etc.); and notification by third parties that could be helpful for staff working on the dynamic documents (e.g. weather forecast). As a result of this categorization, the collaborative working software tool was structured in three main sections (Figure 13), where most of the requirements proposed are included. The three sections are the document library, the project plans, and the miscellaneous elements. A brief overview of the three sections is given below:

- **Document Library Element:** This section contains documents and forms that are used and created for all projects such as the quality assurance register and forms, the review and audit forms and reports, the forms and documents of the integrated management system (IMS – ISO9001, OSHAS 18001, ISO14002) and all other standard forms used in the organizatio's processes. The main folders contained in this section can be seen in Figure 13**;**

- **Project plans Element**: This section contains project specific elements related to on-going projects and archived previous projects. These elements cover planning and forecasting information related to the following areas: project coordination, commercial, procurement, design, and installation at site. These main folders are illustrated in Figure 13;

- **Miscellaneous elements**: This section is important to simplify the notification sent by third parties (Health and Safety executive, BBC weather forecast) and regulatory bodies which the organization is member of (CWCT, Regulatory body for construction). These notifications are currently sent by e-mails to an individual member who distributes the updates as appropriate. With the new requirements identified, these notifications and updates will be sent automatically as RSS feeds to the dashboards of concerned staff members.
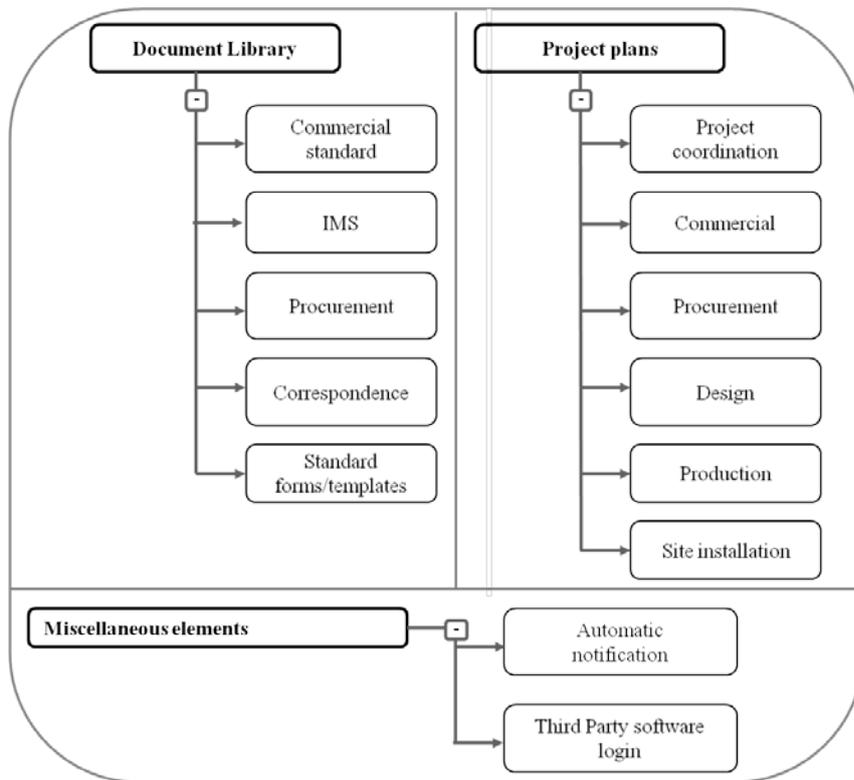
FIG. 13: Main folders and sub folders of the collaborative working software

Each of these sections contains a number of folders (or sub-sections) that contain in turn a number of documents. For example, the project plans section (Figure 13) contains six folders (i.e. project coordination, commercial, procurement, design, production, site installation). Each folder contains a number of project specific documents. Table 5 reports all the documents contained within each folder of the project plans section, the access and editing rights which have been identified from the enterprise models created (IDEF0 maps and DSM) and important notes such as the automatic notifications that should be provided. The post scenario development is purely technological and consists in the development of the software by the IS specialist and the implementation of the functional requirements captured by the method within the software.

Table 5: List of requirements and elements contained in the project plan section of the collaborative software

		Project plan elements		
Section	**Sub-section**	**Elements**	**Access rights**	**Notes/Specific feature**
Project co-ordination		Project schedules (master plan, installation program, component tracking sheet)	- All internal and remote staff	- Once schedules are updated, site managers can receive an automatic notification
		Assessment of statement	- All internal and remote staff	
		Operation & maintenance manual	- All internal and remote staff - Third party (client)	

Commercial		"Potential variation form register"	- Design, procurement, production, site managers, project coordinator, and management	- Commercial director receive a notification of any changes to this document.
				- A column will be added to inform when meetings with client are due to take place
		Sub-contracts signed with sub contractors	- Commercial department, all dept directors, third part (subcontractors)	
		Contract scope of work agreed	- All internal and remote staff	
		Monthly order book and retention held record	- Commercial department, operation, finance and managing directors	- The finance and managing directors receive automatic notification of changes.
		Tender vs actual report	- Commercial department and all dept directors	
Procurement		Placed purchase orders	- All internal and remote staff. Only procurement can edit.	- Rates and price are omitted. - Contract number and area number need to be included in the PO to enhance the search facility - POs are hyperlinked to drawings files of the building elevation within the drawings section
		Weekly delivery report	- All internal and site staff	- Site managers are notified when this document becomes available
				- Omission is flagged up to procurement until the action is completed
		Summary of POs placed per project	- All internal staff	- Commercial department are notified when this document becomes available
	Supplier assessment	- Assessment criteria - Suppliers' OTIF (On Time In Full)	- All internal staff and third party (suppliers)	
Design		Design planned hours	- All staff can access/view - Only design can edit	- It is issued weekly
				- Previous issues are retained and can be seen
	Receipt of info	Drawings from architect/contractor	- Design - Architect can upload drawings	- Mandatory prompt will request a specific descriptive title for drawings
	Work in progress	Drawings in progress	Design department, project coordinator, production director, managing director, and operation manager.	- Once completed, CAD dept will move them into the "issue of approvals" area
	Issue of approvals	Drawings issued for approval	- Architect - Design - Project coordinator, production director, operation director and managing director	- If drawings are not reviewed within 10 working days, this is flagged up to the architect
				- If no further change is needed, drawings are submitted to the "AFC" area
	AFC (Authorized for Construction)	AFC (Authorized for Construction)	- Should have 5 layers: Production, CAD, Commercial, procurement, Project-coordinators.	- Electronic highlighting system (with colors) is used to highlight the progress in each department

				- Production currently operates a paper based.	- Software is used to mark up and hyperlink POs and dispatch notes to drawings
				- Director can review all 5 layers and comments	- The "percentage complete" (e.g. 0%, 25%, 50%) of each layer is displayed and maintained by each department responsible of the layer
	Production drawings.	Production hours (planned vs actual)	- Production director - Commercial dept, project coordinator, operation director and managing director on a read only basis	- Weekly update will be flagged up to production dept. - Previous issues are retained and can be seen.
		Cutting list and production drawings	Design dept, Production dept, and project coordinator.	- As the cutting list moves into the production, it can be removed by the production dept to the "Archive cutting list" folder
		"Archive cutting list" folder	- Production dept, project coordinator, site managers, and design	- Project coordinator knows which items are in production and the AFC layer will soon reflect this change.
Site	Delivery notes to site	- Delivery notes manually marked - Factory GDN	- Site managers, procurement - Accounting	- Delivery notes are marked manually to show any discrepancy and then scanned and saved in "Delivery notes to site"
	Archive delivery note to site	- Delivery notes dealt with by accounts	- Accounting	- The accounts dept after entering each delivery note onto the account system for payment archive the scanned document into "archive delivery note to site"
		- Risk assessment report	- All internal and remote staff - Third parties (client, sub-contractors)	
		- Methods statement, access statement and other set-up requirements	- All internal and remote staff - Third parties (client, sub-contractors)	

6. CONCLUSION

This paper first presented a set of guidelines for the selection of the right modeling method. The authors, after a thorough review of the available literature and modeling methods, found that a modeling tool should be selected as a function of: the purpose of modeling, the ease of communication between stakeholders, the characteristic of the modeling environment and characteristic of the modeling technique itself. The paper then presented a structured and organized methodology for enterprise modeling based on the combined use of the IDEF0 technique and the DSM. The methodology consisted in an innovative, intuitive and powerful approach to understanding complex interactions within the entire operation of organizations, whilst facilitating the management of change and creating a shared vision of business processes. To test and validate the effectiveness of the Enterprise Modeling methodology presented in this paper, the whole operation of construction manufacturing company was modeled. Then, enterprise models were used to define the requirements for a working collaborative software tool with the objectives of eliminating inconsistencies and providing the right information to stakeholders at the right time. From a comparison with the requirements previously captured by a consultant, through interviews with staff members, it was found out that many important requirements were omitted by the consultant. Although models were difficult and time consuming to draw, the results provided contributed to significantly simplify the initial stage of requirements gathering and most importantly, to increase the likelihood of project success as the system will be highly likely business driven rather than technology

driven. The methodology proved to be a valuable tool for modeling large enterprise processes; and in the specific case of the definition of the requirements for the collaborative software it contributed not only to fill the communication gap between the organization (end user) and the system-developer, by communicating the real business need, but also provided a way that assured the involvement of all staff members affected by the project. In addition to the benefits of providing the functional requirements for the collaborative software tool, the enterprise models were also seen by the organization as an effective graphical means to communicate the quality manuals and procedures to staff members so they can be easily understood and complied with and as a starting platform to update quality manuals, when required. In addition, the organization highlighted that the shifting from departmentalized organization to process based organization is now clearer to achieve. This is the result of all business functions (departments) mapped as sub-processes under the main business process called "project delivery process".

From the results, benefits and limitations shown during the application of the methodology, the authors outlined the future development and potential applications of the methodology. First, in order to overcome some limitations of the IDEF0 technique, such as the lack of data storage and poor sequential representation, the authors will assess the possibility of combining the IDEF0 technique with some other IDEF techniques such as the IDEF3 (process description capture) to provide a way for logging data and documentation associated with a process. Second, the authors will use the methodology in business process reengineering to help organizations in the migration from a departmentalized arrangement to a process based arrangement.

7.

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